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A STATUS REPORT ON THE LIVERMORE-ROCKEFELLER-FERMILAB NEUTRINO MASS EXPERIMENT

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A Status Report on the Livermore-Rockefeller-Fermilab Neutrino Mass Experiment

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ABSTRACT

We are performing an experiment to determine the electron neutrino mass with the precision of a few eV by measuring the tritium beta decay energy distribution near the endpoint. Key features of the experiment are a 2 eV resolution electrostatic spectrometer and a high-activity frozen tritium source.

Now is an exciting time because, after a six year startup time, the neutrino mass determination experiments are coming to fruition. We have been setting up an experiment at Lawrence Livermore National Laboratory for the last three years and expect to be taking data this year.

Our approach to this measurement is to use frozen tritium as the source and an electrostatic spectrometer to measure the decay electron energy spectrum. Frozen tritium as a source offers a number of unique features. First, tritium molecules allow precise calculation of final state effects as was discussed in detail at this meeting by Professor Kolos. Binding the molecules in solid tritium results in a perturbation of less than 0.1 eV and are of no consequence to present generation experiments. Second, it offers the highest activity tritium source for a given dE/dx energy loss. With the counting rate near the endpoint being so low, having a high activity source is important to making a neutrino mass determination at the few eV level. Third, techniques exist to determine the dE/dx loss precisely by electron scattering experiments using gaseous hydrogen and deuterium beams. These features make frozen tritium a very attractive source. Since Professor Kolos discussed the final state effects in substantial detail, we refer the reader to his work in these proceedings, and continue with a discussion of our experiment.

For a finite neutrino mass, the Kurie plot significantly deviates from a zero mass straight line within about five neutrino masses from the zero mass endpoint. Actually, the major deviation is within two m_ν of the endpoint. In order to see the mass effect on the Kurie plot, one would ideally have a spectrometer resolution at least comparable to m_ν if not several times smaller. With an appropriate source, an experiment with sufficiently high resolution, can clearly see the finite mass, the final state and the dE/dx effects.

We have designed a system with a resolution of less than 1 eV. This high resolution was achieved by an appropriate choice of the source and system. The spectrometer has three parallel grids, the outer of which are at ground potential. The potential on the center grid is varied to allow only those electrons with an energy greater than the potential of the grid to pass through. The wire diameter, wire spacing, and grid spacing determine the depth of the potential well between the center grid wires. Choosing a 2 eV well depth gives an effective resolution of less than 1 eV.

With our grid plane design, the spectrometer resolution is primarily determined by the angle of the electrons with respect to the electric field in the spectrometer. Electrons entering at an angle to the spectrometer axis actually follow a parabolic path and the spectrometer determines the axial momentum component of the electron. Thus to get 1 eV level resolution it is important to collimate the electrons to be nearly coaxial. We found that a beam collimated to within 14 milliradians of the spectrometer axis gave a change in acceptance from ten to ninety per cent in a 3 eV range. This resolution from our integral spectrometer corresponds to a differential resolution, such as obtained by a magnetic spectrometer, of about 2 eV. We made the collimator adjustable in length because the resolution gets better as the electrons are more tightly collimated. On the other hand, the counting rate drops as the square of the collimation angle. The collimator has been designed to give resolutions between 1 and 20 eV.

The electrons passing through the center grid are accelerated back to their incoming energy as they leave the spectrometer. They then pass through a three lens system focussing them into a 5 cm diameter spot at either a solid state detector or a microchannel plate. The solid state detector has about a 1.5 KeV energy resolution which discriminates against any background electrons which may migrate about the vacuum vessel.

We originally planned to put in a large diameter source which faced downstream. After initial setup, we found that a background resulting from photon-to-electron-conversions in the spectrometer center grid plane turned out to be much worse than expected. Because a tritium source gives rise to a large photon background from atomic deexciataion and electron

Bremstrahlung in the source backing, we made a simple modification to our design. We turned the source around, decreased its diameter, and gathered the emerging electrons in the electrostatic analog of an optical parabolic reflector with the source at its focus. The emerging electron beam is parallel and heading downstream. This technique allowed a much smaller source to give us nearly the same rate by gathering electrons from a much larger solid angle. The smaller source decreased the number of photons and it also shielded the grids from the photons since it points upstream.

The apparatus has been thoroughly tested but further work is necessary to fully realize the original design. The present spectrometer is actually a low-resolution version of our original design. When various materials compatability problems prevented early completion of the 1 eV spectrometer, we built a lower-resolution spectrometer for initial use. We found that this spectrometer had a 4 eV FWHM resolution when measuring the 7.3 keV cobalt line. This resolution is good enough for initial studies and allows work to continue on other aspects of the experiment until 1 eV resolution is required.

A second major effort required to meet our original design is to complete the cryogenic tritium source. We expect this work to take the rest of this year. While completing the cryogenic version, we are using tritium implanted in aluminum foil as a source. The tritium is held very stably in the aluminum oxide layer, leading to minimal contamination. This foil has the further advantage of being much easier to handle than a cryogenic tritium source. Unfortunately, lack of calculable final state effects prevent a determination of the neutrino mass to better than 10 eV with this source.

The cobalt resolution measurements were made using a microchannel plate and a phototube in place of the solid state detector. We are currently installing the solid state detector and expect it to be operational soon. This detector will have a low enough background rate to allow measurements very near the endpoint. During the course of these measurements, we plan to complete the cryogenic components and perhaps install the high resolution spectrometer.

We would like to thank Professor J. Tran Thanh Van for his remarkable efforts these past twenty years in organizing these Moriond meetings. It has been a real pleasure to work with him, his family, and his staff on this meeting. Professor Tran's dedication to bringing together the right people, the right topics, and the right atmosphere for highly stimulating physics meetings has been highly successful. We all hope that the next twenty years will continue this tradition.

Finally, let us thank the sponsoring agencies, the Centre National de la Recherche Scientifique, the Commissariat a l'Energie Atomique, and the Lawrence Livermore National Laboratory for their joint sponsorship of this meeting.

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